

Resource Integration Based Institutional Framework for Sustainable Drinking Water Arsenic Contamination Mitigation and Management

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Abstract: Ground water Arsenic contamination has exponentially endangered the human life and complicated the efforts for obtaining and maintaining drinking water quality standards. The deadly contaminant (Arsenic) has created an alarming and catastrophic crises world over, especially in South Asia e.g., Bangladesh, India, Nepal, Vietnam, China and Myanmar who are facing ground water arsenic contamination problems (Islam, 2005). Every affected country is combating the arsenic contamination menace within the framework of their own socio-economic, legal and cultural perspectives which may not be cost-effective and efficient in time and space matrix. The reason might be of devoid of integration approach amongst the key stakeholders. Hence, under the circumstances, there was a dire need of an integrated approach to combat the arsenic contamination which has virtually emerged as a crises situation, thus necessitating formulation of national action plan for arsenic mitigation. Strategies and objectives within the action plan framework are based on the earlier initiatives of addressing the serious issue of arsenic contamination which includes, establishing integrated institutional arrangements and developing capacity, coordination mechanism amongst all the implementing agencies / stakeholders, like, government(s), NGOs, donor agencies and other related departments & organizations (NAPAM, 2005). The prudent institutional arrangements will make policy decisions and legislation to implement resource integration based arsenic mitigation which includes monitoring and surveillance of water quality/ aquifer mapping / treatment and data base thereof, establishing case diagnosis / treatment of affected arsenicosis patients under health department, developing effective and sustainable behavioral change communication strategies. It will also include community participation / social mobilization and developing cost-effective water treatment technologies and establishment of research related infrastructures. The resource integration based action will converge all the financial, technological and human resources in achieving desired objectives cost-effectively, both qualitatively and quantitatively.

Keywords: Arsenic Contamination, Resource integrated approach, Coordination, Community Mobilization, Geo-Hydrology

1. Introduction

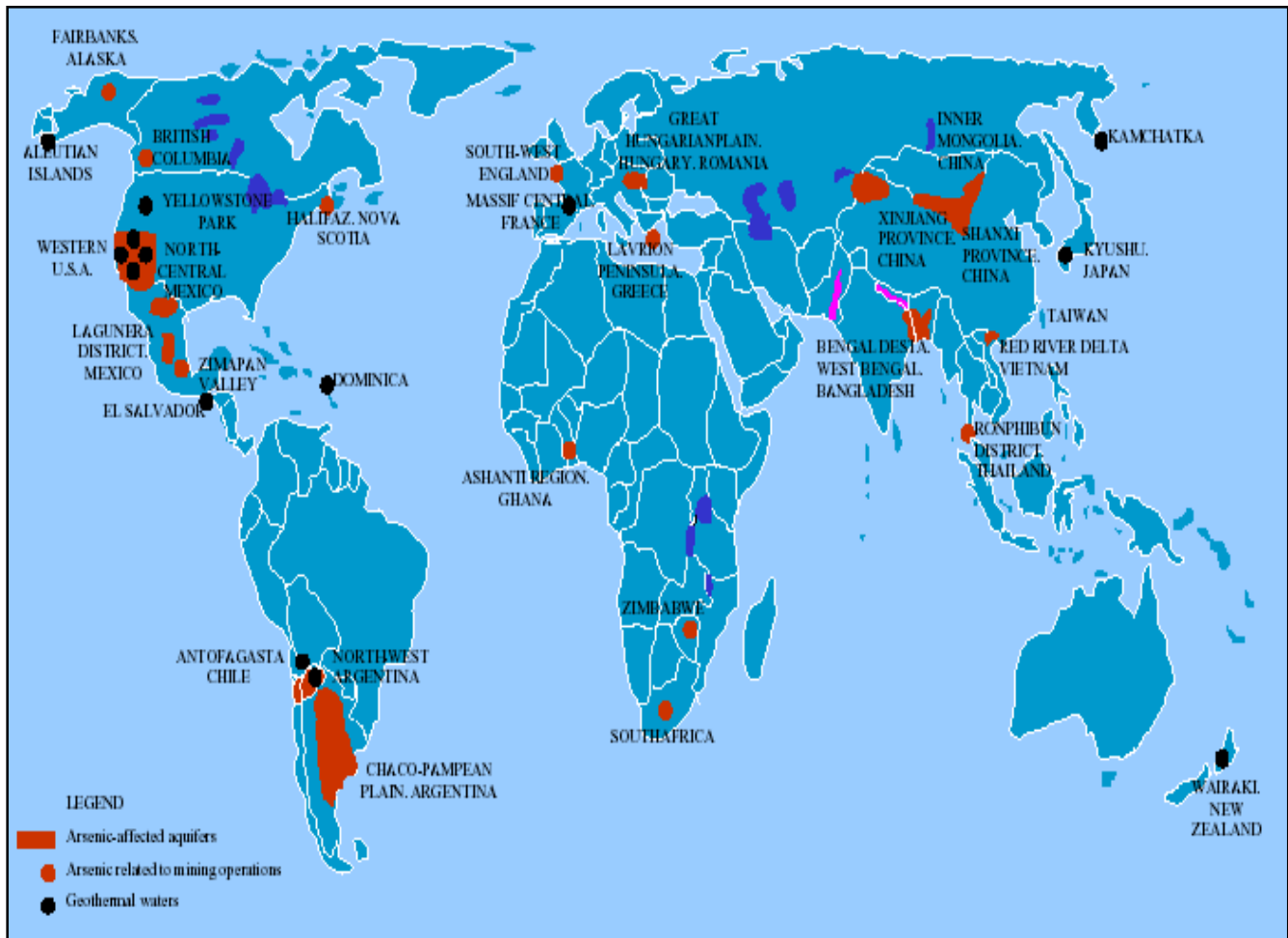
The occurrence, origin and mobility of arsenic in natural waters have received significant attention in recent years. Mobilization of arsenic in groundwater is governed by the geochemical processes involving leaching of continental rocks as well as sediments. Anthropogenic inputs particularly due to the application and use of arsenical wood preservatives as well as pesticides could also lead to significant emission of arsenic in groundwater, especially under anoxic conditions. The risk for arsenic contamination

in groundwater is, therefore, higher than in surface waters. Arsenic contaminated groundwater as the primary source of drinking water in several countries / areas has particularly accentuated the problem because of the effects of arsenic exposure on human health (Bhattacharya et al, 1998).

The concentration of arsenic in natural waters, including groundwater, is typically below the WHO guideline values for arsenic in drinking water of 10 µg/L. However, arsenic mobilization in water is favored under some specific

geochemical and hydro-geological conditions, arsenic concentrations can reach two orders of magnitude higher than this in the worst cases (Smedley, 2005). Most of the extensive occurrences of high-arsenic groundwater are

undoubtedly of natural origin and not due to the discharge of pollutants at the land surface (World Bank Report). The worldwide distribution of arsenic contamination in groundwater is shown in figure-1, below;



Source: Modified after Smedley and Kinniburgh, 2002,

Figure 1. Worlds Distribution of Arsenic in Groundwater and Environment

In China, arsenic has further been identified in the provinces of Jilin, Qinghai, Anhui, Beijing, and Ningxia reported at Regional Operational Responses to Arsenic Workshop in Nepal (26-27 April, 2004). In India, further affected states are Assam, Arunachal Pradesh, Bihar, Manipur, Meghalaya, Nagaland, Uttar Pradesh and Tripura.

Major alluvial plains, deltas and some inland basins composed of young sediments are particularly prone to developing groundwater arsenic problems. Several of these aquifers around the world have now been identified as having unacceptably high concentrations of arsenic. These include not only the alluvial and deltaic aquifers in parts of Asia, but also inland basins in Argentina, Chile, Mexico, the south-western United States, Hungary, and Romania. Important differences exist between these regions, but some similarities are also apparent (World Bank Report). The majority of the high-arsenic groundwater provinces are in young unconsolidated sediments, usually of Quaternary age, and often of Holocene deposition of less than 12,000 years in age.

Many of the world's aquifers with high arsenic levels are located in those areas of Asia where large alluvial and deltaic plains occur, particularly around the perimeter of the Himalayan mountain range. In South Asia, naturally occurring arsenic in groundwater was initially identified in West Bengal, India, and in Bangladesh in the early 1980s and 1990s respectively. Since then governments, donors, international organizations, NGOs, and research institutions have increased testing of groundwater sources. As a result, naturally occurring arsenic has now been identified in the groundwater of the countries in South and East Asia.

2. Literature Review

2.1. Arsenic Contamination in Borrego Valley (California) Groundwater Aquifer

Ground water arsenic contamination due to natural and anthropogenic sources has been observed in Borrego valley

groundwater aquifer, California USA. Water testing in the Borrego Valley (BV) groundwater in 6 wells in southern California was carried out to understand the source of arsenic and nitrate in some of its groundwater production wells. The results show that the arsenic values range from <2 ppb to 12.2 ppb for different wells respectively. The results showed that the arsenic concentration increased 270% for the well no. ID1-10 since 2004 and showed an increase of 63% since 2013 respectively. For other wells the results showed an increase of 147% and 72% since 2001 (The sources of arsenic In Borrego valley - Mohammad et al -2014)

2.2. Arsenic Contamination in Ground Water Impacts 70 Million Lives in India

The parliamentary estimates committee, chaired by member parliament, Mr. Murli Manohar Joshi, in its first report on arsenic in ground water, has criticized the central government for neglecting this serious issue that impacts at least 70 million people across six states (water network research, 2014- Times of India, 29 Dec, 2014).

2.3. Ground Water Arsenic Contamination - Pakistan

In Pakistan, arsenic contamination is one of the emerging issues due to serious health concerns. Arsenic in drinking water poses considerable threats to human health as it can cause or aggravate the various types of cancers of the lungs, bladder, skin, prostate, kidney, nose and liver (NAPAM 2005). In this regard, Pakistan council of research in water resources (PCRWR) and UNICEF (WES), Pakistan office have undertaken many initiatives since 1999. These initiatives include arsenic monitoring as well as mitigation efforts. According to findings, the arsenic problem is comparatively intense in the districts of Central Sindh province and Southern Punjab province of Pakistan. In the province of Punjab, over 20 percent and in the province of Sindh, around 36 percent of the population is exposed to arsenic contamination over 10 ppb (Uqaili et al, 2012). It may be reasonable to disregard the presence of some arsenic in the water, but beyond 50 ppb is considered dangerous. A recent study on prevalence of arsenicosis confirmed the presence of 40 cases in the study population, giving a prevalence 140/100,000. At the same time, there is no road map or action plan encompassing institutional arrangements to mitigate this emerging threat. Therefore, a need was felt to integrate all the resources on the concept of "right based integrated approach" by involving all the stakeholders to address ground water arsenic contamination effectively both qualitatively and quantitatively.

2.4. Current status of Arsenic Contamination in Pakistan - an Epidemiological Survey in Seven Districts of Punjab-IPH November 2003

Out of 38794 surveyed population, 28545 individuals were screened for arsenicosis, following results were observed from the screened population, as shown in table-1, below;

Table 1. Epidemiological survey results in seventeen districts of Punjab province-Pakistan

Category of Arsenicosis	Cases	Prevalence / 100,000 population
Clinical Arsenicosis	3	11
Border Line Arsenicosis	37	130
Total (Clinical + Border Line)	40	140

Overall 24 % of population is drinking water above the minimum permissible level recommended by WHO. District Multan has exceptionally high proportion of (74 %) followed by Rahimyar khan and Muzafar Garh (28.0 % and 23 % respectively). An estimated 11.32 millions of population in seven districts is drinking water with arsenic contents above minimum permissible level recommended by WHO. The proportion is highest for Multan (2.62 million) followed by Rahimyar Khan (1.01 million) .

2.5. Arsenic Contamination in Sindh Province-Pakistan -

SAFWCO, an NGO, conducted ground water arsenic survey, in central Sindh and as per the research report no.4, (SAFWCO ,2004), the following aspects are highlighted;

- A total 67556 samples were collected from 218 union councils of 19 talukas of Dadu, Khairpur, Nawabshah and Tharparkar.
- Out of 67556 samples, 14856 (22 %) samples carry the arsenic contamination ranging from 10 – 500 ppb. However, 4317 (6%) samples carry the arsenic contamination ranging from 50 – 500 ppb.

3. Objectives within the Action Plan Framework

The overview of earlier initiatives of addressing this serious issue of arsenic contamination (a toothless but deadly contaminant) has resulted the need of formulation of national action plan for arsenic mitigation with following objectives;

- To establish resource integration based institutional arrangements for sustainable arsenic mitigation strategies and action planning.
- To evolve coordination mechanism amongst all the planning and implementing agencies at various levels of administration with government(s), NGOs, donor agencies and other related departments.
- To promote legislation, policy development and strategy formulation on arsenic mitigation such as making arsenic testing compulsory and establishing guideline values
- To establish monitoring and surveillance of water quality/ aquifer mapping / treatment and data base system.
- To enable developing cost-effective & sustainable water treatment technologies and establishment of applied research studies institutions and infrastructures.

4. Methodology

Keeping in view the scope & extent of problem enormity, in terms of its ill impacts on human health, there is need to develop an institutionally supported, resource integration based, time bound and sustainable national action plan for arsenic mitigation. This exercise will entail lot of coordination with related government, non-government organizations, arsenic affected communities, researchers, donor agencies and technical institutions & universities.

Extensive field visits, meeting with federal, provincial and district levels government officials were planned and carried out for working out institutional arrangements. Detailed study of water testing reports were carried out to prioritize work plans and inputs from effected communities who played major role in assessing the severity of problem.

The resource integration based and institutionally owned / supported action plan has been evolved on the principal of integrated approach and stakeholder's participatory concept at gross-root level (district level government and community level).

The prevalence of ground water arsenic contamination in Pakistan and world over has been taken as a serious threat to human life and up-front challenge which can pose enormous problems to quality of life to effected population. Arsenic contamination mitigation involves wider, prudent and tangible coordination mechanisms amongst all the stakeholders, which is recommended to be possible by adopting following sequence of planning process and methodologies matrix;

4.1. The Planning Process

- | | |
|----------|--|
| STEP I | Data and arsenic contamination statistics were collected from the available information held with Pakistan Council Research in Water Resources (PCRWR) and from Non-Governmental Organizations working on this particular problem. From in-depth study and analysis of this data, planning parameters were evolved. |
| STEP II | Models of various countries facing similar problems were studied to arrive at cost-effective methods to combat groundwater arsenic contamination in Pakistan. All the principal actors and other stakeholders were consulted broadly, including Environmental Protection Authority (EPA), local government, United Nations Agencies (UNICEF), NGOs, bilateral and multilateral donor agencies. |
| STEP III | Several meetings were held with concerned government departments, scientific organizations, technical universities, national and international NGOs to consider the objectives and goals of the National Plan of Action for Arsenic Mitigation in Pakistan. |
| STEP IV | Programme modalities and modus operandi |

to initiate preparation of provincial plans of action were decided by holding meetings with local government authorities. Two provincial-level workshops were arranged each in the province of Punjab and Sindh to deliberate on the intended plans of action.

- | | |
|-----------|---|
| STEP V | Several orientation meetings of experts and their counterparts in the provinces were held to integrate the provinces into the National Action Plan of Action for Arsenic Mitigation. |
| STEP VI | The main areas of concern in the provinces and federating units were identified and Technical Groups for identification of tangible core issues were suggested. Consequently, a provincial seminar on "Arsenic Contamination in Drinking Water in Punjab" was held on April 12 -13, 2004 in Lahore. |
| STEP VII | Two days seminar on 'Safe drinking water supply in Sindh Province on arsenic problems and mitigation measures' was held on June 1-2, 2004 in Karachi, Sindh province - Pakistan |
| STEP VIII | A national seminar on 'Safe drinking water on health aspects of arsenic contamination' was organized by the Ministry of Health and WHO on March 22, 2005 in Islamabad. |
| STEP IX | Finally, two days national workshop on "Integrated approach for making arsenic free drinking water" was organized. In this workshop, five years National Action Plan for Arsenic Mitigation (NAPAM, 2005-09) was discussed / deliberated thread barely by the participants. |
| STEP X | In the light of recommendations made by the various technical groups in the national workshop, the proposed national action plan for arsenic mitigation was modified and sent for the approval of the Government. |

5. Results and Discussion

Valuable first hand information and experiences were gained from the field visits, interacting with various NGOs & organizations and effected communities. It was noticed that overlapping of efforts were being made by various agencies in addressing the arsenic contamination which was sheer wastage of scarce resources. Therefore, keeping in view above, resource integration based, institutionally supported & owned arsenic mitigation action plan has been envisaged.

5.1. Major Components of National Action Plan for Arsenic Mitigation (NAPAM)

The salient components of institutional arrangements framework for resource integration based action plan for arsenic mitigation is shown in figure-2, below;

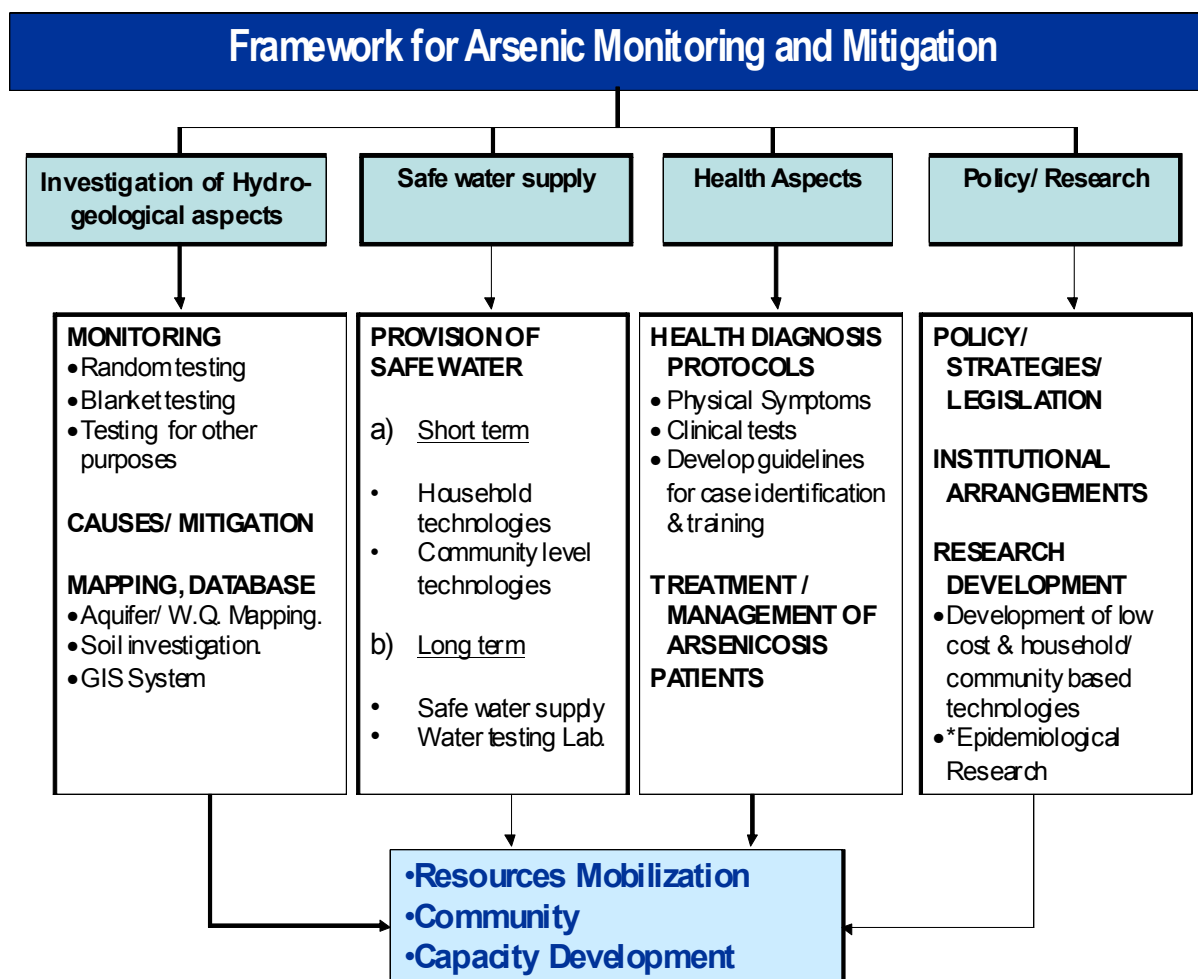


Figure 2. Institutional Framework components of national action plan for arsenic mitigation-Pakistan

5.2. Components and Activities under Action Plan

Broadly, the national action plan for arsenic mitigation embodies the remedial measures varying technologically and is termed as plan components. Each planned component has a set of well defined activities, as mentioned in figure-2 , above. These components are

1. Hydro-geological investigation and water quality monitoring (mainly include screening of water sources, monitoring of screened water sources, aquifer mapping/data base and ground water management.
2. Alternative water supply which includes provision of safe drinking water in high risk areas, treatment of ground and surface water, rain water harvesting and sustainable mechanism monitoring and surveillance at different levels and capacity building along with social mobilization.
3. Diagnostic and case management (mainly includes creating awareness, behavioral change through social mobilization / education, communication, capacity development at various levels, arsenicosis case diagnosis protocols, and arsenicosis case management.
4. Development of arsenic removal technologies

comprising of house hold arsenic removal filters and development community based arsenic treatments.

5. Monitoring and evaluation which includes monitoring of the activities being undertaken at various levels of supervision and implementation to facilitate the management for timely decision making to ensure qualitative and quantitative out comes.
6. The importance of community involvement and participation in arsenic mitigation is highlighted specifying the roles and responsibilities envisioned for local government, Union Councils, as well as involvement of NGOs and the private sector in mobilizing communities and enhancing their capacity for effective participation are outlined and enhancing the Government's devolution policy.
7. Evolving prudent mechanics of making this National Action Plan operational and sustainable. The amount and potential sources of – human, material and institutional – required for the proposed activities, including monitoring and evaluation system/protocol .
8. Finally, as a starting point for future discussions, sample protocols for the entire spectrum of activities will be and are prepared .

5.3. Institutional Arrangements for Arsenic Mitigation Action Plan

5.3.1. National Steering Committee on Arsenic Mitigation

Formation of national committee on arsenic mitigation was formulated for;

1. Establishing institutional arrangements conducive to ownership and developing capacity in arsenic mitigation by the government and other stakeholders.
2. Establishing coordination mechanisms and technical groups on various aspects of arsenic mitigation i.e to regulate the works of various organizations at the national level. The proposed composition of the committee is given below:
 - a. Chairman -Secretary ministry of Science and technology.
 - b. Vice Chairman - Chairman Pakistan Council of research on Water Resources
 - c. Director General Ministry of Health
 - d. Director General Ministry of Environment
 - e. Director General Ministry of Education
 - f. Director General Local Government , Punjab province

- g. Director General Local Government , Sindh province
- h. Director General Local Government& Rural Development, KPK province.
- i. DG LG&RD, Baluchistan province
- j. Director General Local Government& Rural Development, AJ&K province
- k. Director General Health Department of all the Provinces
- l. Director General Public Health Engineering Department
- m. Representative of World Health Organization (WHO)
- n. Representative of Research Institutes
- o. Representative of technical universities
- p. Representative of-UNICEF

5.3.2. Coordination Mechanism Process Flow

Prudent coordination mechanisms amongst all the stakeholders is the hallmark of success of resource integration approach. The coordination process flow path has been shown in figure-3, below;

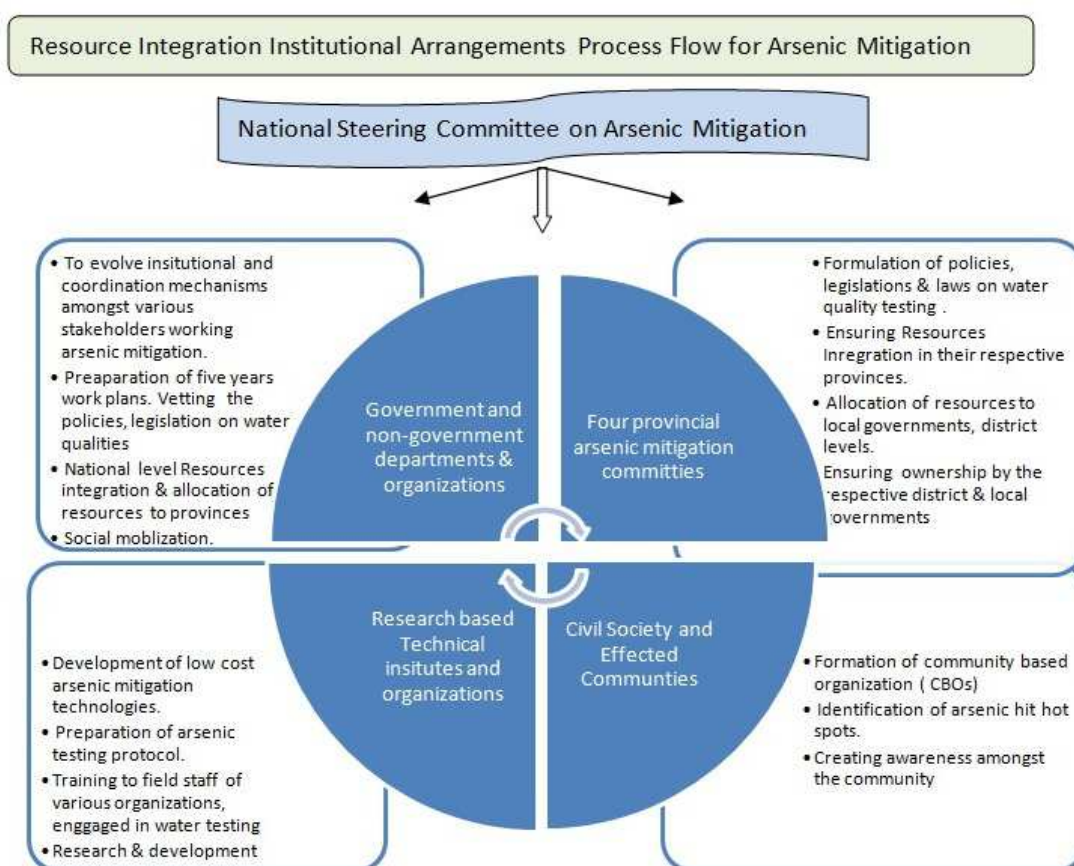


Figure 3. Coordination mechanisms path ways amongst various stakeholders

5.3.3. Role and Functions of National Steering Committee on Arsenic Mitigation

The National Steering Committee on Arsenic will be the

supreme administrative and technical body with the following roles and functions:

1. Integration of the national resources (government and non-governmental) for the purpose of arsenic

mitigation.

2. Assignment of specific tasks and division of responsibilities to various ministries, departments and agencies with the view to avoid overlapping of efforts and resources available for the purpose.
3. Formulation of policies, guideline values and water quality standards. The steering committee will also formulate legislative proposals (for approval of Parliament).
4. Allocation of human and material resources to various agencies involved in arsenic mitigation measures.
5. Competent authority to grant administrative approval up to Rs 5 M.
6. Establishment of priorities, scope, and timelines of mitigation efforts.
7. Approval of the arsenic mitigation technologies and methods.
8. Generating financial support through national and international donors.
9. Monitor ongoing projects at federal level.
10. Authorized to make and approve amendments in ongoing projects.
11. Advise/apprise Council of Environment regarding latest progress of the action plans.
12. Chalk out/modify objectives of Action Plan.
13. Review Action Plan implementation methodologies.
14. Apprise donor agencies of progress of projects.
15. Monitor ongoing projects at federal level.

5.3.4. Proposed Administrative Management at Provincial Levels

All the provinces will have be having administrative

management committee comprises of related government line departments , with following functions and roles;

1. To develop/endorse provincial plans;
2. To monitor progress of projects;
3. To compile and forward monthly progress reports to federal management;
4. To allocate financial and manpower resources within the province;
5. To liaise with donor agencies; and
6. To set priorities for planned projects.

5.3.5. Functions, Roles and Responsibilities of Administrative Management at District Level

1. To implement proposed / approved projects and various arsenic mitigation measures.
2. To work out execution plan in the light of area / ground specific requirements for smooth and cost-effective execution.
3. To monitor the ground progress v/s planned progress.
4. To ensure timely provision of resources for execution to the concerned agencies.
5. To liaise with the technical managements for necessary assistance.
6. To prepare and analyze progress reports and thereafter to ensure their timely submission to higher authorities.
7. To supervise the on going projects and carry out surprise checks / inspection of the projects sites.
8. To confirm community involvement, CBOs monitoring /participation

5.3.6. Hydro-Geological Testing Strategies

The salient water sampling /testing strategies have been described in figure-4, below;

Testing Strategies	
•	Random testing/ survey/ screening (representative sampling strategies encompassing dispersed sampling in an arbitrary manner of @ 5 samples in an area of 1*1- 5*5 sq km);
•	Blanket testing/survey (systematic sampling covering all water sources in a specified area). This is more intensive sampling strategy will be adopted at hot spots/high risk areas.
•	Priority targeted survey/sampling and immediate sampling strategies will be adopted for the most critical areas.
•	Other strategies , During drilling, sampling at various depths with varying horizontal distances to determine contamination distribution patterns and testing, for probable causes by analyzing soil strata.

Figure 4. Guidelines for arsenic contaminated water sampling strategies

5.3.7. Hydro-Geological Activities

The detailed hydro-logical activities are appended in table-2, below;

Table 2. Arsenic mitigation activities – hydro-geological

Activities/	Location WHERE	Action WHAT	Implementation HOW	Responsibility WHO	Time frame WHEN
Identification of the high risk areas/hot spots in order of	All un-surveyed districts of all provinces	Consulting available information, data and ground checks	Coordination by TMAs under direction of technical organizations	*DGLGs *PCRWR *NGOs	*Immediate in target districts i

Activities/	Location WHERE	Action WHAT	Implementation HOW	Responsibility WHO	Time frame WHEN
priority				*TMAs	
Testing/ survey/ screening of water sources, survey and blanket testing	Affected District , as per district committee	* Sample testing *Blanket screening	*Painting with *Green – safe *Red – unsafe *100% testing of hot spots	* *DGLGs *TMAs PCRWR	Immediate
Monitoring of screened water sources	List to be prepared by PCRWR in consultation with provinces	*Screened sources to be monitored twice a year *Soil sampling *mapping *prep of GIS	*Checking for arsenic contamination *Water table variation *Soil analysis for causes of arsenic release into water	PCRWR TMAs UCs District labs *Geological Survey of Pakistan *WAPDA *Survey of Pakistan *private entrepreneurs (with superior equipment for conducting such investigations)	Immediate, in coordination with all concerned
Soil investigation and aquifer mapping	*High-risk Areas *All areas specified by provinces.	*Collection of arsenic- related data *Detection of contaminated and arsenic-free aquifers to source supply of arsenic- free groundwater.	*checking for other contaminants *Preparation of GIS for future works		Immediate , after approval national action plan for arsenic mitigation
Groundwater management for irrigation	Arsenic- contaminated areas	*Save water losses. *Crop irrigation as per water requirements	*Lining of irrigation channels *Scientific watering of crops *Education of farmers *Research on arsenic release including: *natural causes *pesticide use * industrial effluents	*Irrigation Dept. *Agriculture Dept. *TMAs. *UCs	Immediate Concurrent activity along with other actions
Research & Development on arsenic releases	Arsenic-affected areas	Investigation of all parameters	*Publication of manuals * On site demos. *Training Workshop	*PCRWR *PhD scholars *Technical Universities *PHED other interested parties	Ongoing
Capacity development	*All concerned staff – LGs *Volunteers *Educational Institution staff	On-the-job-training of all concerned		*PCRWR *DGLGs *TMAs *UCs	Immediate
Resource mobilization – tangible and intangible	*Target community *Volunteers (schools, colleges and social organizations)	*Raising financial and human resources * Formation of Task Force for motivating public. *Utilizing the services of the NGOs (NCHD, Edhi Trust, etc.)	*Arranging funds Govt PC-1 *Seeking contributions from international donors *Encouraging local donors/NGOs	PCRWR MoE *Provincial govt, *Local Govt *Donor agencies *TMAs *CCBs *UCs *Imams *Local Govt	As early as possible after approval of the NAPAM
Community participation	Segments of the people in the affected areas	*Motivation of having quality life *Provision of some material incentives		*TMAs *UCs *NCHD *Spiritual Figures *Imams *TMAs	Simultaneous activities Along with the action plan
Development of protocols & SOPs		* Elaboration of activities and methods	Writing the modus operandi for each activity	*PCRWR *PCSIR * UCs PCRWR	At start of the National Action Plan
Preparation of GIS	Affected areas	Computerized mapping		*GSP *Private Sector	Forthwith

5.3.8. Alternative Water Supply Strategies

The short term alternative safe water supply strategies are mentioned in figure-5, below;

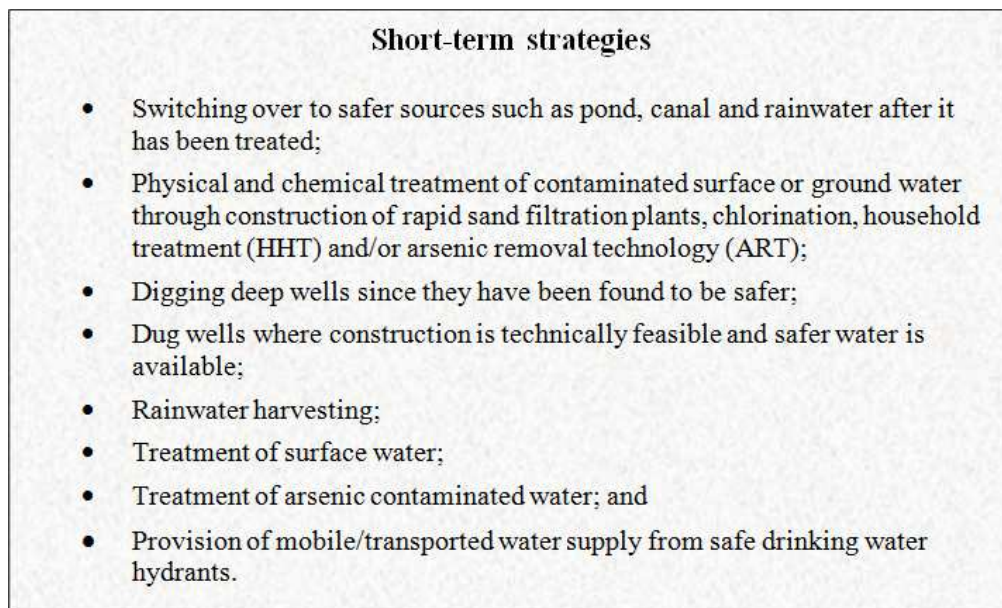


Figure 5. Guidelines for chalking out arsenic free & safe alternative water supply measures/ strategies

Likewise , long term alternative water supplies strategies and detailed activities log frame can also be worked as per the format , given in table-2, above, to make a sustainable, cost-effective and low cost indigenous arsenic removal

technologies.

The schematic representation for sustainable arsenic mitigation model, with shared responsibilities and ownership by all the stakeholders is shown in giure-6, below;

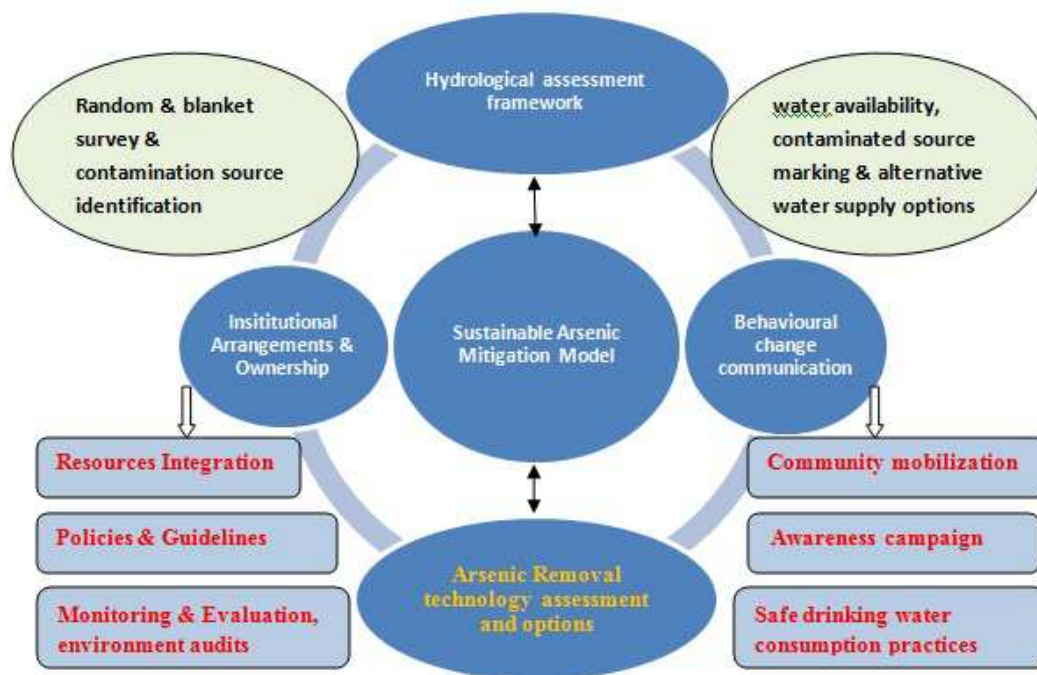


Figure 6. Schematic representation and inter connection amongst various arsenic mitigation stakeholders, components and activities.

6. Conclusion

The adverse impacts of arsenic contamination on human health are seriously threatening the quality of life of arsenicosis patients, especially in developing countries due to

lack of awareness and devoid of systematic approaches for early identification and treatment. Though, such countries have undertaken arsenic mitigation programmes, yet they could not achieve the desirable results due to divergent mitigation approaches. Lack of prudent institutional

arrangements, behavioral change communication strategies for community awareness & mobilization, resource integration based approaches and negligible government buying are the major contributing factors towards not achieving the desired arsenic mitigation objectives.

Therefore, there is a dire need of having result oriented and efficient institutional arrangements with focused functions and duties, coupled with shared interconnections with all the stakeholders for carrying out time bound arsenic mitigation activities. The resource integration approach will assist in convergence of efforts with visible outcomes.

Acronyms

ART	Arsenic Removal Technology
EPA	Environmental Protection Authority
GIS	Geographical Information System
GSP	Geological Survey of Pakistan
HHT	Household treatment
HRDS	Human Resource Development Society
HAS	Health Services Academy
IPH	Institute for Public Health
LG&RD	Local Government and Rural Development
MCLG	Maximum Contaminant Level Goal
MoH	Ministry of Health
NCCWS	National Coordination Committee on Water and Sanitation
NEQS	National Environmental Quality Standards
PCRWR	Pakistan Council of Research in Water Resources
PCSIR	Pakistan Council of Scientific and Industrial Research
PEPC	Pakistan Environmental Protection Council
PHED	Public Health Engineering Department
PM&EC	Planning Management and Evaluation Cell
ppb	parts per billion
SAFWCO	Sindh Agricultural and Forestry Workers Coordinating Organization
SDO	Sub-Divisional Officer
SHED	Sindh Health and Educational Development Society
TMA	Tehsil Municipal Administration
TMO	Tehsil Municipal Officer
UNICEF	United Nations Children's Fund
WAPDA	Water and Power Development Authority
WHO	World Health Organisation

References

- [1] Ahmad, T, Kahlowan, M. A, Tahir, A, & Hifza, R. (2004), "Arsenic an Emerging Issue: Experiences from Pakistan", Paper Presented at 30th WEDC International Conference Vietiane, Lao PDR.
- [2] Bhattacharaya, P., Larsson, M., Leiss, A., Jacks, G., Sracek, A., Chatterjee, D., 1998b. Genesis of arseniferous groundwater in the alluvial aquifers of Bengal Delta Plains and strategies for low-cost remediation (abstract). In: Proc. Int. Conf. on As pollution of ground water in Bangladesh: causes, effects and remedies. Dhaka, Bangladesh, Feb. 8-12, 1998.
- [3] Islam ul Haque (2005), Ground Water Arsenic Contamination Integrated Approach For Making Arsenic Free Drinking Water National Action Plan For Arsenic Mitigation (NAPAM, 2005-09), Geological Society of America Abstracts with programs Vol 37, No.7 P.454
- [4] IPH (2003) Prevalence of Arsenicosis due to Ingestion of Arsenic through Drinking Water: An epidemiological Survey from Seven Districts of Punjab. Institute of Public Health, Government of Punjab (Supported by UNICEF).
- [5] Mohammad Hassan Rezaie-Boroon, Chaney J, Bowers B (2014) The Source of Arsenic and Nitrate in Borrego Valley Groundwater Aquifer, Journal of Water Resource and Protection 2014, DOI: 10.4236/jwarp.2014.617145, PP. 1589-1602
- [6] NAPAM (2005), National Action Plan for Arsenic Mitigation Pakistan, Public by Ministry of Environment, Government of Pakistan Islamabad.
- [7] PCRWR (2003a) Arsenic Contamination in Groundwater of Southern Punjab. PCRWR, Ministry of S&T, Government of Pakistan (Supported by UNICEF).
- [8] PCRWR (2003b) Innovative Low Cost Arsenic Removal Technologies for Developing Countries. PCRWR, Ministry of Science & Technology, Government of Pakistan (Supported by UNICEF, Pakistan).
- [9] PCRWR (2004) Arsenic Contamination in Groundwater of Central Sindh. PCRWR, Ministry of S&T, Government of Pakistan (Supported by UNICEF).
- [10] PCSIR (2000). Ground Water Studies for Arsenic Contamination in Northern Punjab, Pakistan, Phases I&II, PCSIR, Islamabad (Supported by UNICEF).
- [11] SAFWCO (2003) Survey & Testing for Arsenic Mitigation Programme: Khairpur and Dadu Districts. Agricultural & Forestry Workers Coordinating Organization-SAFWCO, Sindh, (Supported by UNICEF).
- [12] Smedley P (2005), Arsenic occurrence in groundwater in South and East Asia, Published in: Towards a More Effective Operational Response: Arsenic Contamination of Groundwater in South and East Asian Countries. Report No. 31303. Volume II Technical Report The World Bank.
- [13] Times of India (2014), Arsenic in groundwater impacts 7 crore lives: Panel, *The Times of India*, December 12, 2014.
- [14] Uqaili A.A. , Mughal H. A., Maheshwari K. B, Arsenic Contamination in Ground Water Sources of District Matiari, Sindh, August 2012, Volume 3, No.4 International Journal of Chemical and Environmental Engineering
- [15] World Bank Report, (Towards a more effective operational response- Arsenic contamination of ground water in South & East Asian Countries) Volume II technical report by WB & WSP